RESTRICTED CIRCULATION

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Forecasting Septoria in England and Wales IV

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1. Introduction Data on Septoria infection from the National Leaf Disease Surveys for 1970 to 1975 show a strong correlation between percentage of lesions on the second leaf in July, and number of rain days ($\geqslant$ 1mm) in the second half of May and first half of June (Tyldesley 1976, 1977). The amount of disease in the previous season also appears to have a significant effect on subsequent disease in the regions least susceptible to Septoria infection (Beck and Thompson 1978).

There are indications that the level of infection may be reduced by high light intensity (Benedict 1971), and also following 2 consecutive days with minimum temperatures of 7 deg C or less (Shaner and Finney 1976). The remainder of the present memorandum considers the evidence for these constraints applying also to the infection data recorded by the National Leaf Disease Survey (1970–1975).

2. Disease and light intensity Following Beck and Thompson (1978) an assumed linear relation between percentage leaf area infection (I) and number of raindays in the second half of May and first half of June (w) was modified by a linear multiplier (S) representing average daytime light intensity, leading to the relation

$$I = a + bw\,(1 + eS)$$

$$= a + bw + cS \qquad (1)$$

where a, b, c and e are constants. Measurements of light intensity are not made usually and S was represented therefore by bright sunshine (expressed as a percentage of normal for the period), calculated for each region for 6 different periods:

S1 First half of June

S2 Second half of June

S3 First half of July

S4 Whole of June

S5 Second half of June and first half of July

S6 June and first half of July

The effects of carry-over from the previous season were included by rewriting Eq (1) as

$$I = a + bw + cwS + d\,I_{-1} \qquad (2)$$

where I_{-1} was the measured amount of infection in the previous season.

The coefficients in Eq (1) and (2) were evaluated using a stepwise linear multiple regression program, with the variables on the right-hand side of the equations being retained only if the reduction in variance produced by their inclusion corresponded to an F-ratio of at least 3. The infection data were in the form of regional averages and with only 6 years data it was not possible to calculate meaningful equation coefficients for individual regions. Data were grouped therefore as follows:

(a) 4 most susceptible regions (SW, SE, W. Mid., Wales)

(b) Remaining regions

(c) All 8 regions

Results using Eq (1) are given in Table 1. Sunshine data for several of the selected periods showed the expected negative correlation with infection data but there was some inconsistency between the results from the two groups of 4 regions. Sunshine for the first half of July was found to be positively correlated with disease in the case of the 4 most susceptible regions. This was presumably a sampling fluctuation of the sort which might be expected in a set of data where a major part of the variance in the infection data was associated with the number of raindays, and where only a small part of the remaining variance could be linked consistently with sunshine.

An analysis was performed which used sunshine directly in the regression equation:

$$I = a + bw + cS \qquad (3)$$

The results (summarised in Table 2 for those cases where the inclusion of sunshine produced a significant reduction in variance) were broadly similar to those discussed already. In a few cases in the more susceptible regions the inclusion of sunshine produced a reduction of variance larger than that associated with raindays. In general the evidence from both analyses was convincingly in favour of infection being negatively correlated with amount of sunshine.

Results obtained by fitting Eq (2) to the data for 1971-75 showed no significant (negative) correlation between infection and sunshine x raindays for the less susceptible group of regions. However some significant correlations were found for the remaining group of regions, and for all 8 regions taken together: in the former case the sunshine term dominated the reduction of variance. The inclusion of the previous year's infection produced a larger reduction of variance than the inclusion of a sunshine term in the case of the less susceptible group, and for all 8 regions together.

3. Disease and days of low minimum temperatures The postulated relation is

$$I = a + bw + cwD \qquad (4)$$

where D was the number of consecutive pairs of days with minimum temperatures less than or equal to 7 deg C, calculated for the 6 periods given in § 2. n consecutive days satisfying the minimum temperature criterion were counted as (n-1) D-periods. Table 4 shows the result of application of the equation, and

also the results obtained by using a relation in which D appeared additatively:

$$I = a + bw + cD \qquad (5)$$

There was no consistent evidence in favour of the expected negative correlation between infection and periods of low minimum temperature. Results for the more susceptible group of regions were either inconclusive (for wD) or supported the expected correlation (for D), but those from the remaining group of regions indicated an opposite conclusion. Results from all regions together showed no significant contribution to the reduction of variance from either wD or D.

Similar results were obtained when equations (4) and (5), modified by the inclusion of previous year's infection as an extra variable, were applied to data for the years 1971 - 1975.

4. Conclusions There was no consistent evidence for consecutive days with low minimum temperature ($\leq$ 7 deg C) in June or the first part of July having any effect on the levels of infection recorded in July by the National Leaf Disease Survey. However there were fairly convincing indications that sunshine was negatively correlated with disease. From Table 1 a suggested rough working relation which might be tested against data for years other than 1970–1975 is (for all 8 regions)

$$I = 3 + 4w - 0.03wS6 \qquad (6)$$

Any comments or suggestions on this paper should be referred to the authors.

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Table 1. Regression analysis of I, w and wS

Data Set	Variable	F-value on entry	Corr Coeff	Next variable	F-value on entry	Multiple Corr Coeff	Final multiple Corr Coeff	SE of estimate	Final equation
(a)1970-75 SW,SE, W Mid, Wales	w	19.2	.68	wS1	7.5	.78	.78	8.3	(i)
	w	19.2	.68	wS2	3.3	.73	.73	9.0	(ii)
	wS3	22.1	.71	w	0.5	-	.71	9.1	(iii)
	w	19.2	.68	wS4	7.7	.78	.78	8.3	(iv)
	w	19.2	.68	wS5	0.4	-	.68	9.4	(v)
	w	19.2	.68	wS6	0.5	-	.68	9.4	(v)
(b)1970-75 E Mid, E Yorks/Lancs, N	w	27.2	.74	wS1	0.6	-	.74	6.8	(vi)
	w	27.2	.74	wS2	0.6	-	.74	6.8	(vi)
	w	27.2	.74	wS3	5.4	.80	.80	6.2	(vii)
	w	27.2	.74	wS4	0.1	-	.74	6.8	(vi)
	w	27.2	.74	wS5	5.1	.80	.80	6.2	(viii)
	w	27.2	.74	wS6	2.4	-	.74	6.8	(vi)
(c)1970-75 All regions	w	37.8	.67	wS1	1.5	-	.67	8.6	(ix)
	w	37.8	.67	wS2	6.7	.72	.72	8.1	(x)
	w	37.8	.67	wS3	0	-	.67	8.6	(ix)
	w	37.8	.67	wS4	4.4	.71	.71	8.3	(xi)
	w	37.8	.67	wS5	1.0	-	.67	8.6	(ix)
	w	37.8	.67	wS6	4.0	.70	.70	8.3	(xii)

(i)	I = 9.3	+	3.9w	-	0.030	wS1
(ii)	I = 7.9	+	4.0w	-	0.036	wS2
(iii)	I = 2.5			+	0.016	wS3
(iv)	I =11.3	+	4.5w	-	0.043	wS4
(v)	I = 1.4	+	2.0w			
(vi)	I =-2.0	+	1.6w			
(vii)	I =-1.8	+	2.9w	-	0.012	wS3
(viii)	I =-1.1	+	3.4w	-	0.019	wS5
(ix)	I =		1.8w			
(x)	I = 2.8	+	3.3w	-	0.023	wS2
(xi)	I = 3.7	+	3.0 w	-	0.018	wS4
(xii)	I = 3.5	+	3.8w	-	0.025	wS6

Data Set	Variable	F-value on entry	Corr Coeff	Next Variable	F-value on entry	Multiple Corr Coeff	Final multiple Corr Coeff	SE of estimate	Final equation
(a)1970-1975 SW,SE, W Mid, Wales	S1	19.2	.74	w	1.3	-	.74	8.7	(i)
	S2	31.3	.77	w	0.4	-	.77	8.3	(ii)
	S4	38.5	.80	w	0	-	.80	7.8	(iii)
(b)1970-1975 E Mid, E Yorks/Lancs, N	w	27.2	.74	S3	5.1	.80	.80	6.2	(iv)
	w	27.2	.74	S5	4.0	.79	.79	6.3	(v)
(c)All regions	w	37.8	.67	S2	7.7	.73	.73	8.0	(vi)
	S4	38.2	.67	w	4.7	.71	.71	8.3	(vii)
	w	37.8	.67	S6	4.1	.70	.70	8.3	(viii)

(i) $I = 49.3 - 0.29S1$

(ii) $I = 57.9 - 0.47S2$

(iii) $I = 57.4 - 0.41S4$

(iv) $I = 8.7 + 1.7_w - 0.10S3$

(v) $I = 14.2 + 1.5_w - 0.14S5$

(vi) $I = 25.4 + 1.1w - 0.21S2$

(vii) $I = 24.7 + 1.0w - 0.18S4$

(viii) $I = 27.4 + 1.1w - 0.21S6$

Data Set	Variable	F-value on entry	Corr Coeff	Next Variable	F-value on entry	Multiple Corr Coeff	Next variable	F-value on entry	Multiple Corr Coeff	Final Multiple Corr Coeff	SE of estimate	Final equation
(a)1971-1975 SW, SE, W Mid, Wales	wS3	30.1	.79	w	2.5	-	I_{-1}	2.0	-	.79	8.5	(i)
	wS5	31.0	.80	w	1.0	-	I_{-1}	1.3	-	.80	8.4	(ii)
	wS6	31.5	.80	w	0.2	-	I_{-1}	0.1	-	.80	8.4	(iii)
(b)1971-1975 E Mid, E, Yorks/Lancs, N	Inclusion of sunshine terms wS1-wS6 produced no significant reduction of variance											
(c)1971-1975 All regions	w	37.3	.70	I_{-1}	4.2	.74	wS1	3.4	.77	.77	7.8	(iv)
	w	37.3	.70	I_{-1}	4.2	.74	wS4	3.9	.77	.77	7.8	(v)

(i) $I = -3.5 + 0.021wS3$

(ii) $I = -9.4 + 0.032wS5$

(iii) $I = -15.6 + 0.039wS6$

(iv) $I = -3.1 + 2.7w - 0.014wS1 + 0.38I_{-1}$

(v) $I = -1.7 + 3.2w - 0.020wS4 + 0.31I_{-1}$

Data Set	Variable	F-value on entry	Corr Coeff	Next variable	F-value on entry	Multiple Corr Coeff	Final multiple Corr Coeff	SE of estimate	Final equation
(a)1970-1975 SW, etc	Inclusion of D1 - D6 produced no significant reduction of variance								
(b)1970-1975 E Mid, etc	w	27.2	.74	wD1	5.3	.80	.80	6.2	(i)
	w	27.2	.74	wD3	4.7	.80	.80	6.2	(ii)
	wD4	32.1	.77	w	3.0	.80	.80	6.2	(iii)
	wD6	33.9	.78	w	2.7	-	.78	6.3	(iv)
(c) All regions	Inclusion of wD1 - wD6 produced no significant reduction of variance								
(a)1970-1975 SW, etc	w	19.2	.68	D1	10.7	.80	.80	7.9	(v)
	w	19.2	.68	D4	6.3	.77	.80	8.5	(vi)
	w	19.2	.68	D6	5.9	.76	.78	8.5	(vii)
(b)1970-1975 E Mid, etc	w	27.2	.74	D3	4.9	.80	.80	6.2	(viii)
(c) All regions	Inclusion of D1-D6 produced no significant reduction of variance								

(i) $I = -0.7 + 0.9w + 0.18_{w}D1$

(ii) $I = 0.6 + 0.9w + 1.0_{w}D3$

(iii) $I = -0.2 + 0.8w + 0.16_{w}D4$

(iv) $I = 3.4 + 0.23_{w}D6$

(v) $I = 7.8 + 2.4w - 3.3D1$

(vi) $I = 5.0 + 2.7w - 2.3D4$

(vii) $I = 4.8 + 2.6_{w} - 2.2D6$

(viii) $I = -0.6 + 1.Cw + 13.6D3$